

CLAIMS

WHAT IS CLAIMED IS:

1. A permselective membrane assembly comprising a porous, graded particulate layer.
2. The permselective membrane assembly of claim 1 further comprising a porous support and a permselective membrane.
3. The permselective membrane assembly of claim 2 wherein the porous support is selected from the group consisting of alumina, titania, silica, zirconia, perovskites, spinels, pyrochlores, zeolites, stainless steel, and combinations thereof.
4. The permselective membrane assembly of claim 3 wherein the porous support comprises alumina.
5. The permselective membrane assembly of claim 2 wherein the permselective membrane is deposited by CVD.
6. The permselective membrane assembly of claim 2 wherein the permselective membrane comprises silica.
7. The permselective membrane assembly of claim 2 wherein the permselective membrane comprises nanosil.
8. The permselective membrane assembly of claim 1 wherein the permeance to hydrogen gas is at least 1×10^{-7} mol/ m² s Pa and the hydrogen permselectivities with respect to carbon dioxide, carbon monoxide and methane are each at least 100.
9. The permselective membrane assembly of claim 1 wherein the permeance to hydrogen gas is at least 4×10^{-7} mol/ m² s Pa and the hydrogen permselectivities with respect to carbon dioxide, carbon monoxide and methane are each at least 800.

10. The permselective membrane assembly of claim 1 wherein the porous, graded particulate layer is prepared from a plurality of sols having narrow particle size distributions.
11. The permselective membrane of claim 10 wherein a least one of the sols has an average particle size of greater than 400 nm and at least one of the sols has an average particle size less than 100 nm.
12. The permselective membrane of claim 10 wherein the plurality of sols are comprised of alumina particles.
13. A method for promoting the yield of a gaseous reaction product by selective permeation using a permselective membrane assembly comprising a porous, graded particulate layer.
14. The method of claim 13 wherein the gaseous reaction product is hydrogen.
15. A sol comprised of alumina particles having a median particle size of at least 50 +/- 25 nm.
16. A sol comprised of alumina particles having a median particle size of at least 200 +/- 75 nm.
17. A sol comprised of alumina particles having a median particle size of at least 600 +/- 200 nm.
18. A method for producing a stable boehmite sol having a narrow particle distribution comprising;
 - hydrolyzing an aluminum-containing precursor at conditions sufficient to form an aluminum-containing intermediate;
 - peptizing the aluminum-containing intermediate with an acid at conditions sufficient to form a colloid; and
 - aging the colloid at conditions sufficient to form a stable sol.

19. The method of claim 18 wherein the aluminum-containing precursor is selected from the group consisting of aluminum alkoxides, aluminum chlorides, and aluminum isopropoxides.
20. The method of claim 18 wherein the hydrolysis step is performed at temperatures in the range of 340 K and 370 K.
21. The method of claim 20 wherein the hydrolyzation step is performed at times in the range of 0.5 hours and 72 hours.
22. The method of claim 18 wherein the acid is selected from the group consisting of nitric acid, hydrochloric acid, acetic acid, citric acid, or tartaric acid or combinations thereof.
23. The method of claim 18 wherein the peptization step is performed at a molar ratio of H^+ /Alkoxide in the range of 0.03 and 0.25.
24. The method of claim 23 wherein the peptization step is performed at times in the range of 1 hours and 20 hours.
25. A boehmite sol produced by the method of claim 18.
26. A method for preparing an aluminum-containing solution comprising mixing a boehmite sol with a binder-containing solution, wherein the boehmite sol is produced by a method comprising:
- hydrolyzing an aluminum-containing precursor at conditions sufficient to form an aluminum-containing intermediate;
 - peptizing the aluminum-containing intermediate with an acid at conditions sufficient to form a colloid; and
 - aging the colloid at conditions sufficient to form the sol.

27. The method of claim 26 wherein the binder is selected from the group consisting of polymers and polyelectrolytes.
28. The method of claim 27 wherein the binder is a polymeric binder selected from the group consisting of polyvinyl alcohol, polysaccharide, starch, stearic acid, polylactic acid, polymethylmethacrylate, polysulfone, polyimide, polyvinyl pyrrolidone, polyacrylamides, hydroxyethylcellulose, guar gums or other water-soluble polymers.
29. The method of claim 28 wherein the polymeric binder is polyvinyl alcohol.
30. The method of claim 29 wherein the aluminum-containing solution comprises polyvinyl alcohol in the range of 0.035 wt% and 3.5 wt%.
31. The method of claim 30 wherein the aluminum-containing solution comprises boehmite sol in the range of 0.015 and 1.5 M.
32. An aluminum-containing solution produced by the method of claim 26.
33. A method for forming a porous membrane comprising:
coating a porous support with an aluminum-containing solution having a first particle size; and
calcining the support at conditions sufficient to convert the aluminum-containing solution to a gamma-alumina layer;
wherein the aluminum-containing solution comprises a boehmite sol and a binder-containing solution and wherein the boehmite sol is produced by a method comprising:
hydrolyzing an aluminum-containing precursor at conditions sufficient to form an aluminum-containing intermediate;
peptizing the aluminum-containing intermediate with an acid at conditions sufficient to form a colloid; and
aging the colloid at conditions sufficient to form the sol.

34. The method of claim 33 wherein the coating and calcining steps are repeated at least once using an aluminum-containing solution having a second particle size, the second particle size being smaller than the first particle size.
35. The method of claim 34 wherein the porous support is selected from the group consisting of alumina, titania, silica, zirconia, perovskites, spinels, pyrochlores, zeolites, or any combination thereof.
36. The method of claim 35 wherein the porous support is alumina.
37. The method of claim 34 wherein the coating and calcining steps are repeated four times.
38. The method of claim 34 wherein the gamma-alumina layer has a thickness in the range of 200 nm and 2,000 nm.
39. The method of claim 38 wherein the gamma-alumina layer has a thickness in the range of 400 nm and 1,800 nm.
40. The method of claim 39 wherein the gamma-alumina layer has a thickness in the range of 500 nm and 1,500 nm.
41. A porous membrane produced by the method of claim 33.
42. A method for preparing a composite membrane comprising:
coating a porous support with an aluminum-containing solution having a first particle size;
calcining the support at conditions sufficient to convert the aluminum-containing solution to a gamma-alumina layer; and
depositing a silica layer on top of the gamma-alumina layer;

wherein the aluminum-containing solution comprises a boehmite sol and a binder-containing solution and wherein the boehmite sol is produced by a method comprising:

hydrolyzing an aluminum-containing precursor at conditions sufficient to form an aluminum-containing intermediate;

peptizing the aluminum-containing intermediate with an acid at conditions sufficient to form a colloid; and

aging the colloid at conditions sufficient to form the sol.

43. The method of claim 42 wherein the silica layer is deposited on the gamma-alumina layer by chemical vapor deposition.

44. The method of claim 42 wherein the silica layer has a thickness in the range of 10 nm and 50 nm.

45. The method of claim 42 wherein the silica layer has solubility sites of less than 0.3 nm size.

46. A composite membrane produced by the method of claim 42.